Intraoperative assessment of cerebrovascular reserve capacity during tumor resection with BOLD fMRI

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Introduction: Cerebrovascular reserve capacity (CVR) in patients with ischemic neurovascular disease is a well established and useful clinical risk assessment tool. The application of CVR to brain tumors has a very interesting potential due to the correlation between increased vascularity and tumor malignancy.[1] Moreover, the tumor core and rim have heterogeneous response to vasoactive stimuli. Therefore CVR mapping may help separating intra and peri-tumor tissues. Intraoperative cerebrovascular reactivity determination at the tissue level may impact on patient management and guide surgical intervention, by assessing the effectiveness of surgery for brain tumors inducing a remodeling of the vasculature.

By modulating the partial pressure of CO_2 ($PACO_2$), the CVR capacity can be estimated using functional MRI. The $PACO_2$ influence the smooth-muscle tone in the arterioles: a $PACO_2$ increase induces vasodilatation, and therefore increases the cerebral blood flow (CBF) and the Hb concentration, which changes can be dynamically images using BOLD fMRI sequences. CVR is defined as the reactivity of the vessels to $PACO_2$ changes.[2]

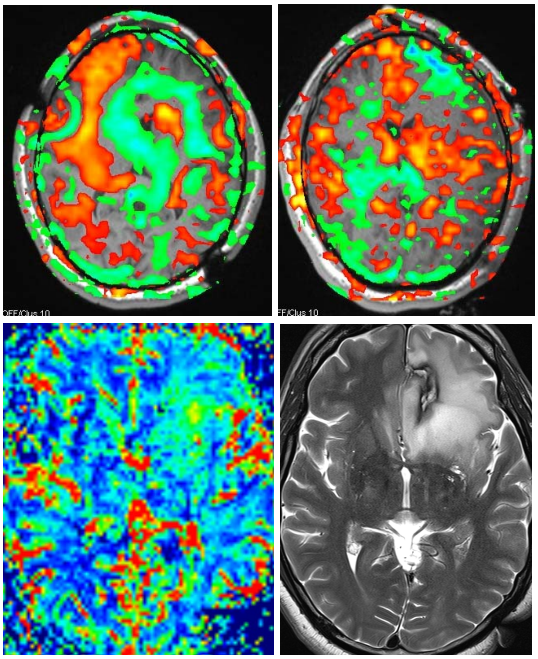
We demonstrate the feasibility of CVR determination with fMR intraoperatively and show very different vascular responses to surgical tumor resection.

Methods: During surgical tumor resection, 8 anesthetized patients (2 females, 6 males, age range 7 to 46 years) were scanned on a 3T Siemens Skyra VD13, with an intraoperative 8 channels headcoil (NORAS MRI products, Höchberg, Germany).

CVR was measured by manipulating the $PACO_2$ between hyper and hypocapnic states,[3] with the following paradigm: 3x[44s baseline, 44s high CO2, 44s baseline]+22s baseline, during the acquisition of an axial 2D BOLD fMRI sequence with voxel size:3×3×3 mm^3, acq. matrix 64x64, 35 slices with interleaved acq., slice gap 0.3 mm, GRAPPA factor 2 with 32 ref. lines, adaptive Coil Combination, Auto Coil Selection, TR/TE 2000/30 ms, flip angle 85°, bandwidth 2368 Hz/Px, 220 volumes.

The GLM statistics was performed with motion correction, spatial filter width 4.0 mm, modeled transition states, and temporal highpass filter.

Results: Positive cerebrovascular reactivity is color-coded from red-yellow-white (t-values = 2 to 8), negative CVR in green-cyan-dark blue (t-values = -2 to -8).



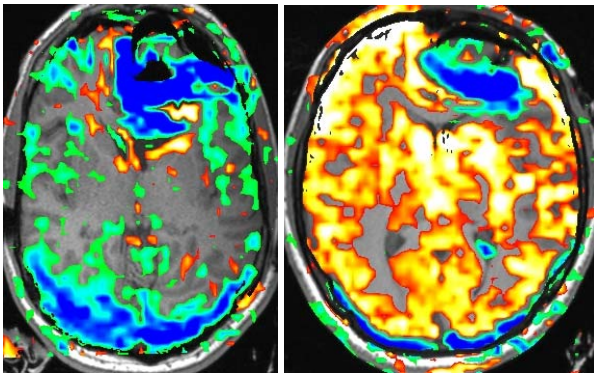


Figure 2: *Left panel: a 38 years old male showing negative CVR after tumor resection. Right panel: A 42 years old female showing positive CVR after tumor resection. NB both show a negative response in the stagnant blood.*

Figure 1: *A 43-year old male, with a frontal tumor.* ***top-left panel****: prior to tumor resection the CVR upstream from the tumor is dominated by the tumor blood steal (green), in accordance to perfusion MRI data.* ***bottom-left panel****: MR perfusion data showing higher cerebral blood volume within the tumor* ***bottom-right panel****: the tumor with remodeled vasculature.* ***top-right panel****: after the tumor resection, a normalization of CVR is observed in the brain tissue (red).*

Conclusion: Intraoperative CVR measurements during tumor resection were possible and demonstrated very different response pattern to surgery. Such spatial information may potentially provide useful clinical information as to better understand tumor hemodynamics and for determining tumor borders. The inhomogeneity of the receive array coverage is to be considered for accurate CVR diagnostics.

References:

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